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A Transactional Environmental Support System for Europe

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Abstract: Human society developed through technological revolutions. Centralisation began with agriculture. An industrial revolution then led to strongly urbanised societies. Unfortunately, agriculture, industry and urbanisation now threaten the biosphere on which humans depend. Biodiversity conservation focussed on protection until Convention on Biological Diversity also emphasised sustainable use and an ecosystem approach, with local knowledge, monitoring and empowerment for adaptive management. However, conservation through use of biodiversity and ecosystem services is an aspect of multifunctional land-use that is socio-economically and ecologically complex. It requires knowledge support for local decisions that are made much more often than statutory environmental assessments, and thus too frequently for all to be guided by experts. The TESS project (www.tess-project.eu) is designing a system to collate and automate local delivery of all ways to leverage biodiversity enhancement throughout Europe, aiming to (i) predict impacts of small-scale actions on incomes and biodiversity, (ii) monitor results of the decisions that follow such prediction and (iii) inform central assessors to enable appropriate tuning of regulatory and fiscal incentives. If the information revolution can rebuild local knowledge in cooperation with central decision-makers, perhaps it can maintain a diversity of species, environments and cultures that sustains humanity.

Keywords: Biodiversity; Ecosystem Services; Monitoring; Adaptive Management; EIA.

1. CHANGING HUMAN IMPACTS AND CONSERVATION CONCEPTS

Human societies developed agriculture separately in all the major continents, leading to settlements, specialisation and varying degrees of centralisation [Bronowski 1973]. Further increase in density and urbanisation accompanied industrialisation, which started in Europe more than two centuries ago, spreading to North America a century later and recently to many more countries. A consequence of the specialisation and centralisation was rapid advance in scientific knowledge, so that pressures of human population growth have been accompanied for more than a century by increased understanding of links between human societies and their environment [Diamond 1997]. Concepts at first academic, about anthropogenic climate change [Arrhenius 1896], resource depletion [Ehrlich & Ehrlich 1970] and biosphere feedback mechanisms [Lovelock 1979], have become wide concerns.

In Europe, adverse development can be constrained (under 85/337/EEC) after Environmental Impact Assessment (EIA) at local level [e.g. Treweek 1999] and more recently (under 2001/42/EC) following Strategic Environmental Assessment (SEA) at higher level [Wood & Jeddow 1992]. These high-level directives, and protection of areas (e.g. Habitats Directive, 92/43/EEC), may halt loss of biodiversity by 2010 at continental level. However, the current system of assessment is bottlenecked by dependence on experts, which limits application to large or severe cases and can also prejudice repeatability in conflictive ways [Therivel 2004]. The complexity of assessment is daunting, especially when Sustainability Impact Assessment (SIA) includes social and economic sustainability factors as well as the environment [Jacobs & Sadler 1989, Therivel & Minas 2002]. Moreover, a challenge not met by the current system of assessments, is to influence the myriad decisions made by individuals at local level, on what to remove or plant and how and when to manage it. Decisions that are made for farm fields and gardens are small-scale individually, but summate to change the environment.

The limitations of protective measures were foreseen in the Convention on Biological Diversity (CBD) that came from the Rio de Janeiro Summit in 1992. CBD covers protection of species and habitats in just 2 of 19 substantive Articles, but considers use of the components of biodiversity in 13 of those Articles, notably recommending to: "protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements" (Article 10); and "adopt economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity" (Article 11).

The complementation of protection by "incentive-based conservation" [Hutton & Leader-Williams 2003] is important, because globally the majority of land is not protected. Reserve creation peaked in the 1980s [Pretty 2002] and extension much past the current 12% of land protected globally may not be socio-economically feasible, despite estimates from species-area curves indicating that retention of biodiversity requires the application of conservation measures to some 50% of the land surface [Soulé & Sanjayan 1998]. The problem is that protection of habitats and species creates opportunity costs [Swanson 1992, Norton Griffiths 1995]. The resulting reduction in jobs or incomes can cause conflicts for farmers, foresters and fishers [e.g. Redpath et al. 2004] and even local poverty [Adams et al. 2004], with a resulting dichotomy of land use into areas (i) exploited intensively to produce food and other materials or (ii) protected for science, aesthetics or to prevent extinction of species. The alternative, a dual approach to conservation [Inamdar et al. 1999], envisions a "biodiversity friendly mosaic of land uses driven by the livelihoods that are derived from the sustainable use of wild living resources, instead of landscapes with small islands of biodiversity in a sea of agriculture" [Hutton & Leader Williams 2003].

Fortunately, Europe is moving towards a broader basis for conservation than a focus on protection of species and habitats. The Natura 2000 network specifically includes provision for use of wild resources, for example through hunting. Earlier fears that consumptive use of biodiversity risks a "tragedy of the commons" [Hardin 1968] are being replaced by community-based conservation [Berks et al. 1989, Ostrom et al. 1999]. Protection remains an important indication that society values wild species, and protected areas can play an important role for supporting core populations that render harvest more productive in surrounding areas [Roberts et al. 2002]. However, extractive use too is seen as desirable in many nature reserves, to maintain human practises that preserve habitats [Getz et al. 1999].

2. ECONOMICS FOR CONSERVATION THROUGH USE OF BIODIVERSITY

For a global stocktaking of human impacts on the biosphere, the Millennium Ecosystem Assessment (2004) introduced a further utilitarian concept: 4 types of ecosystem services. "Supporting" and "regulating" services benefit society as a whole and can therefore be considered public goods, to be sustained by public funding (e.g. agri-environment services in the second pillar of a revised Common Agricultural Policy), whereas "provisioning" and "cultural" services often benefit particular sectors in society and become private goods. However, supporting and regulating services do not necessarily require high biodiversity, partly because humans can fill the consumptive role of many other species (especially predators), and there is pressure to reduce funding for a CAP no longer giving cheap food.

Unfortunately "provisioning" through forestry and agriculture also tend to become so intensive that biodiversity suffers, while commercial or subsistence use of wild plants, fish and bush-meat becomes unsustainable. However, the "cultural" ecosystem services have a strong potential for conserving biodiversity. This is not simply a matter of eco-tourism, in which high-carbon travel may associate with high pressure on local water and other resources, but also of local communities gathering flowers, angling or hunting as much for recreation as for food, and developing rules to keep the service sustainable. For more than two millennia, wildlife reserves have been created for hunting [Gadgil & Guha 1992], with modern recreational hunters and anglers adding closed seasons, quotas, catch and release. Religions that preserve wildlife species are prevalent where human populations are dense, and the Q'ran records early sanctuaries at Makkah and Medina.

Where land is relatively unproductive, cultural use of wild resources frequently competes effectively with intensive uses, for example where hunting is more economic than livestock farming in southern Africa [papers in Prins et al. 2000], and hunting has restored endangered wildlife populations through management and reintroduction much more widely [papers in Dickson et al. 2009]. However, where soil fertility and climate combine to give high productivity, as in Europe, there is less land on which sustainable use of wild resources is more cost effective than intensive cultivation or other development. Moreover, the residual low-productivity areas tend to be refuges for rare species, which can (ironically) inhibit conservation through sustainable use of wild resources. Grouse moors are an example [Redpath et al. 2004]. In rapidly developing areas, fertile and accessible land which is not either protected, valuable for recreation or covered by construction tends to be used mainly for cultivation. New crops, such as bio-fuels, open more areas to cultivation and, as cultivation intensifies, biodiversity is lost.

There is a risk that polarised attitudes to polarised landscapes are again focusing conservation efforts on protected areas, while scope for restoring biodiversity elsewhere is overlooked. Studies repeatedly show that small de-intensification measures can have major impacts at little cost. Newton (2004) identified the main factors associated with decline of 30 bird species as: (i) weed control, (ii) early ploughing, (iii) grassland management, (iv) intensified stocking, (v) hedgerow loss & predation. All can be addressed in ways that produce fractional reductions in yield. An early example is a small reduction in cereal crop yields when headland-edges are left unsprayed, which increases abundance of game birds and other wild fauna and flora [Boatman & Sotherton 1988].

Then, if land gives annual income per hectare of I from intensive production, the reduced income from constrained use C should be acceptable if compensated by income U per hectare from use of wild resources:

$$C + U \geq I$$

This equation (Kenward & Garcia Cidad 2005) indicates how ecology can be combined with economics for decisions about land-use, and can also accommodate social aspects if measurement of C, U and I is extended from income per hectare to employment or quality of life measures. Moreover, just as the equation $C + U \geq I$ uses ecosystem-service value to leverage biodiversity through minor constraints on crop production, so can U be leveraged with stewardship subsidies S to maximise scope for conservation (i.e. $C+S+U \geq I$). There are already European examples where $C+U \geq I$ without subsidies. For example, where food shortage for deer in conifer plantations results in an uneconomic venison harvest and severe bark-stripping, a small loss of timber through including some deciduous trees can be more than offset by gain in value of deer and reduced damage [Reimoser & Reimoser 1997].

This leveraging approach can in principle be applied to all land, but is there enough value in use of wildlife resources for conserving much biodiversity? The most rigorous data come from surveys of spending on wildlife-associated recreation that are run at 5-year intervals by the United States Department of the Interior Fish and Wildlife Service and United States Department of Commerce Census Bureau. The latest national survey (USDI, FWS & USDC 2007) estimates that 88 million US adults (38% of adults) watched (71m), fished

(30m) and hunted (13m) wildlife in 2006, spending $122 billion. That represents $155 for each of the 774 million hectares of the USA.

In Europe, an FP6 project on Governance and Ecosystem Management for the Conservation of Biodiversity (GEMCONBIO) conducted a large case study on uses of wild biodiversity in the European Union, also during 2006 (www.gemconbio.eu). With help from the Federation of Associations for Hunting and Conservation of the EU, the European Anglers Alliance, the European Council for Conservation of Fungi, and Birdlife International, a high proportion of the 27 EU states in 2006 were covered by the survey for hunting (96%) and angling (64%), 81% for bird-watching and 42% for collecting fungi; other surveys increased the coverage to 100% for hunting and 94% for angling (Table 1).

Table 1. Participated and spend on wildlife-related activities in the EU.

	Proportion of EU population surveyed	Participants (grossed-up) millions	Annual spend € billions
Hunting	**96-100%**	**6.6**	**16**
Angling	**64-94%**	**23**	**19**
Collecting: Fungi	**42%**	[45][1]	
Plant Products	**7%**	[135][1]	
Bird-Watching	**81%**	**6.2**	{8}[2]

[1,2]unreliable due to [low survey%]{few spend data}

With participation in hunting and angling also estimated from licence data, estimates that about 7 million Europeans are recreational hunters and 23 million are anglers are probably reliable. With data from 10-14 countries on spending, it can be estimated that they spend about €35 billion annually, or at least €40 billion if (less reliable) estimates from bird-watching are included [Kenward & Sharp 2008], and that perhaps a quarter of the 490 million EU citizens gather fungi and plant products. This is equivalent to at least €121 for each of the 331 million hectares of the EU, equivalent to $181/ha at the exchange rate in late 2007. In the UK alone, a survey in 2002 estimated annual income from a wide range of wild resources (including collection of plant products and fungi but excluding released game) at €7.2 billion, which was 30-50% the value of UK agricultural production and accounted for some 58,000 jobs [IUCN-UK & ESUSG 2004].

Private recreational spending on wild resources encompasses equipment, accommodation and travel as well as use of land, but there is clearly scope for funding to benefit diversity of wild resources. It was also clear from the survey that although hunting and angling are well regulated and contributing to conservation across Europe, such that ungulate populations are stable or expanding in every surveyed state, much less attention has been paid to the potential contributions from those collecting fungi and plant products, while the relative economic contribution from wildlife-watching is much lower than in the US.

3. GOVERNANCE FOR CONSERVATION THROUGH USE OF BIODIVERSITY

In the same year as the Millennium Ecosystem Assessment was published, the parties to CBD committed at the 7th Conference of Parties to two documents, containing 12 "Malawi Principles" for the "Ecosystem Approach" (CBD VII/11) and 14 "Addis Ababa Principles and Guidelines (AAPG)" on sustainable use of biodiversity (CBD VII/12). These principles give as much consideration to social issues and economics as they do to ecological issues, as also recommended at the World Summit on Sustainable Development of 2002.

A recent review of axioms and principles for sustainable use concludes that benefit-sharing, adaptive management, local empowerment and ecosystem maintenance are almost universal, with integration, multiple scales and realising values common to most [Wall & Kernohan in press]. Frequent recommendation of these principles reflects much qualitative analysis of governance. In particular, adaptive management from local knowledge and monitoring has long been recommended for conservation [Holling 1978]. Demonstration of quantitative associations between these principles and ecosystem services is rare. However, the GEMCONBIO project used 36 cases, from local to international level, to show highly significant positive associations of ecosystem service sustainability with adaptive management. The project also found positive linkage of ecosystem services and biodiversity with external knowledge leadership and community-based management, with regulations playing positive and negative roles.

In 2007, parties to the 1979 (Bern) Convention on the Conservation of European Wildlife and Natural Habitats approved a charter a based on 12 simple recommendations condensed from the Ecosystem Approach and AAPG commitments of CBD (TVPS(2007)7). A charter is a document that agrees responsibility of government towards citizens (effectively conferring rights) as well as responsibility of citizens. Therefore the charter not only has guidelines for users of wild resources, for instance on monitoring and adaptive management, but also for regulators at all levels so that they too can encourage conservation through use of biodiversity. The charter is on hunting and biodiversity, but the 12 recommendations do not specify hunting and are therefore equally applicable to all use of wild species, whether through angling, gathering wild flowers or collecting fungi.

Although the recommendations in the charter are simpler and fewer than in the documents on which they are based, each recommendation involves many guidelines. Moreover, in practical application of the economic considerations in part 2, many crops can be grown on land in different ways, many types of de-intensification applied for different species, potentially using funds from public sources and many private activities applied in different ways. Compared to the simplicity of protective regulation (i.e. to not use this land or not to take that species), conservation through use of biodiversity is complex indeed.

4. TESS: A NEW TOOL FOR COMPLEX SOCIO-ECOLOGY

Much of the damage to global ecosystem services has occurred in the last 50 years. This reflects human population increase, and also improved technology for felling trees and tilling land, but also governance measures. Thus, 50 years of subsidies at continental and state level have successfully driven production based on very few crop species in Europe, and hence on minimal biodiversity. Commercially driven homogenisation of diverse local land-use continues to degrade ecosystem services that sustained Europeans for centuries [Pretty 2002]. Species whose dynamics and colonisation operates at small scale have disappeared through habitat loss and fragmentation, so that biodiversity has declined drastically at local level [e.g. Paine & Pienkowski 1997, Thomas et al. 2004].

Yet, over the same 50 years, scientific knowledge of the environment has also advanced rapidly, so that “Paradoxically we are not limited by lack of knowledge but failure to synthesise and distribute what we know” [Pimm et al. 2001]. As noted above, the synthesis must handle many types of species, land use, wild resource use and regulation based on the need for sustainability, so the calculation process becomes complex. Sophisticated decision support becomes essential. However, during the last 30 years, human ability to integrate information, handle complex calculation and deliver predictions as decision support has increased dramatically, through the use of computers. Forecasts from empirical models, which neglect causation, are being replaced by more accurate prediction from individual-based models that incorporate behavioural processes [Goss-Custard & Sutherland 1997]. Models can be spatially specific through linkage to habitat and socio-economic data as cells in geographic information systems (GIS).

The internet is the way to collate the extensive ecological knowledge that is currently fragmented across Europe, as recognized by important data collation and standardisation initiatives such as GMES, INSPIRE and SEIS. Information from geo-referenced databases at national level is already used by government experts for SEA, and by private consultancies to meet EIA requirements of government in large development projects. Thus the internet increasingly delivers knowledge, computed by experts, to implement commitments of CBD parties in 2004 on environmental assessment. The need now is to include socio-economic data, to meet other commitments at CBD/VII, on incentives, sustainable use and the ecosystem approach. Inclusion of socio-economic data is an asset rather than a complication, because private spending on wildlife-related activities is large and often requires or creates high biodiversity. Such private funding needs to be tapped and used cost-effectively for conservation of biodiversity in Europe.

However, the task of applying private recreational payments to enhance biodiversity, for example through minor constraints on crop production, needs to be done at local level. So do other projects that can offset wider commercial pressures (e.g. farm shops), and tuning to local conditions of other small de-intensification measures (e.g. headlands), public works (e.g. road verges) and gardens that can benefit biodiversity at minimal cost. Moreover, it is the myriad of decisions made locally by individuals (on what and when to plant or remove, what to consume or discard or how to travel) that gradually change the biosphere.

There are can never be enough human experts to handle all the complex knowledge needed at local level to handle decisions that fall outside the scope of SEA and EIA. But what if those individual decisions too could be guided automatically via the internet, in ways as subtle as the red and green underlining in a word processor? An electronic farm-plan could predict income from crops and flash for a buffer strip to reduce nitrate run-off (Table 2). An architect's plan could colour the best sites for solar cladding, or a garden plan offer rewards for a carbon-sequestration scheme. A beep on the GPS-enabled tractor could warn where to avoid mowing rare plants or bird's nests.

Table 2. Examples in modes of operation of an environmental decision support system.

Scale	Question	Operations
Field	Is it too early for the Nymphalis butterfly larvae to cut these nettles in our amenity area now?	*Map on hand-held remote communication device with GPS-auto-location capability.*
Farm	If I use my land like this in future, what happens to my income, game bags and nitrate run-offs?	*Completion of electronic farm plan attracts colour coding and comment on proposed mitigations.*
Parish	How do we route this path to optimise views while minimising erosion and wildlife disturbance?	*GIS-based modelling with 2D/3D views on desk-top PC in local community centre.*
Region	If trends in land-use continue for 20 years, how will BAP targets be affected? Can subsidies ameliorate?	*Statistics plot in government department after country wide distributed parallel processing.*

What if the results of all those decisions could also be reported to central planners, as a GIS for species and habitats in ever-increasing detail, to enable more sophisticated SEA and SIA in exchange for the decision support that benefits local livelihoods and biodiversity? At local level, baseline monitoring and continuing assessment over wide areas could also solve several problems with EIA, enable 'pay by results' to replace 'pay for process' subsidies [Ferrano & Kiss 2002] and stimulate interest in widespread biodiversity restoration (thereby perhaps reducing need for high-carbon visits to distant reserves).

The application of local knowledge for adaptive management inevitably faces the challenge of building a functioning link between local communities and central decision-makers. With the co-financing of the European Commission, an FP7 project is designing a Transactional Environmental Support System (TESS). The aim is to find how best the important data collation and standardisation initiatives such as GMES, INSPIRE and SEIS can be combined with the abundant but disparate environmental research across Europe, for predictive modelling to inform not only SEA and EIA, but also the myriad individual decisions. This will enable the regional authorities and local stakeholders to simulate different scenarios and design policies for optimal decisions.

TESS contends that local communities can restore environments if they are enlightened, empowered and aided by policy-makers and society as a whole, with the use of ICT services. The reasoning is that:

- central planners can collate complex knowledge and incentives to assist local decisions;
  - but they need local information to monitor and adapt their knowledge and incentives policy;
- local managers must gather local information to make and monitor their decisions;
  - so they can exchange this local data for the complex knowledge that benefits their livelihoods;
- the huge volume of local-centre exchanges will need an automated support system.

The automated support system will handle environmental data, but also include information on market economics and government incentives in a way that is both user-friendly and socially integrated. Social integration can be planned partly by survey and partly by trials in local communities across Europe. TESS trials will use GPS-enabled PDAs to map species and habitat, and local projects to benefit biodiversity and livelihoods. Other issues include standardisation of data and models, data security, scaling, and scope for e-commerce.

5. CONCLUSIONS

1. Conservation through use of biodiversity requires complex local decisions, based on species requirements and bio-socio-economic considerations for multi-functional land use.
2. The internet provides a way to bring together widely dispersed predictive models, and to collate complex environmental data, for providing knowledge leadership to local level.
3. The knowledge needs to be delivered to land-managers, in the form of context-adaptive support for decisions on livelihoods and biodiversity, as much as to government planners.
4. Local decision support requires local records of species and habitats, which central government also needs mapped in order to manage the decision support system adaptively.
5. A system in which central decisions makers can exchange decision support to local level for local knowledge would facilitate statutory environmental assessment as well as myriad small local-level decisions that summate to change the human environment.

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